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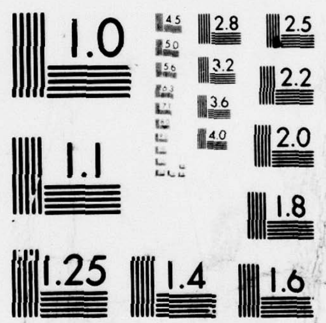

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GROUTING INSTRUMENTATION, OLD RIVER LOW SILL CONTROL STRUCTURE

by

Donnie L. Ainsworth

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Instrumentation was developed and used in the field to monitor the presence and flow of grout during remedial grouting of the Old River Low Sill Control Structure. Measurements were also made of uplift pressures by means of transducers installed in packers in drilled holes through the slab. This report presents information on the development and field use of instruments to detect the presence of grout, the rate of buildup under the base of the structure, and CONT

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pressure increase under the slab due to grouting operations. All data were electronically recorded and were used extensively to regulate the grouting operation.

PREFACE

The development of grouting instrumentation and field measurement of grout flow and pressure at the Old River Low Sill Control Structure were performed for the U. S. Army Corps of Engineers, New Orleans District (NOD), by the Concrete Laboratory (CL), U. S. Army Engineer Waterways Experiment Station (WES), in accordance with authority provided in DA Form 2544 dated 30 October 1973 and subsequent amendments. Mr. E. Burton Kemp, NOD, was responsible for the emergency grouting operation and the instrumentation program was under his direction.

The grouting instrumentation program was conducted during the period 1973-1975 under the direction of Messrs. Bryant Mather, Leonard Pepper, and B. R. Sullivan, CL. Mr. D. L. Ainsworth developed the instrumentation and was project leader for the field measurements. Messrs. B. R. Sullivan and Dale Glass actively participated in the preparation for and in the field measurements. Mr. D. L. Ainsworth prepared this report.

The Directors of WES during the conduct of this test program were COL G. H. Hilt, CE, and BG E. D. Peixotto, CE. The Commanders and Directors of WES during the preparation and publication of this report were COL J. L. Cannon, CE, and COL N. P. Conover, CE. Mr. F. R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	25.4	millimetres
pounds (force) per square inch	0.006894757	megapascals
cubic yards	0.7645549	cubic metres
cubic feet	0.02831685	cubic metres

GROUTING INSTRUMENTATION, OLD RIVER LOW SILL CONTROL STRUCTURE

PART I: INTRODUCTION

Background

1. The instrumentation discussed in this report was developed for the Corps of Engineers, New Orleans District (NOD), for use at the Old River Low Sill Control Structure, Concordia Parish, Louisiana. The need for such instrumentation was recognized when remedial repair work was being planned following the 1973 flood.

2. The Old River Low Sill Control Structure, located approximately 40 miles south of Vidalia, Louisiana, on the west bank of the Mississippi River, was completed in 1960 as part of a project to prevent capture of the Mississippi River by the Atchafalaya River. It is an 11-gated, pile-founded structure approximately 600 ft long and is used to control approximately 30 to 40 percent of the flow of the Mississippi River into the Atchafalaya River.

3. During the 1973 flood, an eddy developed behind the southeast upstream wing wall, and on 12 April 1973 the major portion of this wing wall collapsed. Surveys in the forebay area indicated that a large scour hole had developed in front of gate bays 8, 9, 10, and 11 to a maximum depth of 65 ft. Since this scour hole extended 29 ft below the bottom of the sheet pile beneath the structure, a detailed boring program was carried out by NOD to investigate the foundation beneath the structure and the stilling basin. The borings indicated a cavity beneath the structure and stilling basin in the vicinity of gate bays 6 through 11 that varied in depth from a maximum of 52.2 ft in gate bay 11 to 1.8 ft in gate bay 7. Plate 1 is a photograph of the structure showing a general view from the stilling basin side. Note grouting casings anchored at bridge deck extending to and anchored in lower concrete slab.

4. The Grouting Branch of the WES Concrete Laboratory evaluated approximately 30 grout mixtures* and subsequently recommended several mixtures of low cement content and low-bond-strength grout that would have minimum bond to the supporting steel piling. It was estimated that approximately 30,000 cu yd of level-seeking grout would be required to fill the voids.

Purpose and Scope

5. During the planning stage for the remedial work, the New Orleans District engineers and geologists recognized the need for instrumentation to monitor the flow of grout and uplift pressure during grouting. Personnel of the Engineering Physics Branch, Concrete Laboratory, WES, were asked to attend a planning meeting at the structure to discuss possible instrumentation methods.

6. Members of the staff of WES suggested monitoring the grout flow with a resistivity gage that had received limited attention in the laboratory. It was agreed that WES should develop and build 10 such gages and have them ready for use at the structure upon start-up of the grouting operation.

7. Pressure measurements were also discussed and WES was requested to design a system and provide the design, equipment list, and instructions to the contractor. It was later decided that WES should also monitor the uplift pressure since the contractor had little or no instrumentation experience. It was agreed that WES should provide and monitor up to four pressure gages.

8. This report presents the design and operation of the instrumentation used in support of the grouting operation.

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* Hugh K. Wilson, "Grouting of Scoured Foundation, Old River Low Sill Structure, Louisiana," Miscellaneous Paper C-78-19, Dec 1978, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

PART II: DEVELOPMENT OF GROUTING SUPPORT INSTRUMENTATION

Grout Detector

9. Previous detection of grout in a water environment had been accomplished with some degree of success using pressure differential gages. Since these gages are expensive to fabricate, lack resolution, and are difficult to use in the field, other methods were considered when the problem of monitoring grout movement at a number of locations under the slab of the Low Sill Structure was presented.

10. Two methods which were investigated for detecting grout were: (a) capacitive and (b) resistive. A preliminary laboratory study was conducted to evaluate both methods. Two 1-in. diameter electrodes spaced 1 in. apart were connected electrically to an a-c voltage source as shown in Figure 1. Because of the effect of d-c polarization, an a-c oscillator was used to provide input a-c voltage (V_{in}). An oscilloscope was used to monitor the change in voltage across R_1 as the dielectric was varied between the electrodes of the probe.

11. It was noted in these tests that if the electrodes were insulated, very little voltage change would occur when the probe was inserted in water or grout. It became apparent that a voltage measurement based primarily on capacitance effects would be very difficult. If the metal electrodes were in intimate contact with the surrounding dielectric medium, the capacitance and resistance (impedance) affected the output. The controlling factor for the dielectrics of interest (air, water, and grout) was the resistance change or resistivity of the dielectric.

12. The laboratory tests showed that a significant increase in voltage across R_1 occurred when the probe was inserted in tap water and a greater increase when inserted in grout. This is logical since water is more conductive than air and grout is more conductive than water. Only a small amount of cement added to water increases the conductivity of the water considerably.

13. Using information obtained from the laboratory tests, 12 grout

detectors were fabricated for field application. The gages consist basically of two 1-in. diameter electrodes spaced approximately 1-1/2 in. apart, and protruding from the main body approximately 2 in. The main body was an encapsulation of the extension cable and electrode wire connections and steel balls added for weight. Plate 2 is a photograph of the detector described and smaller detector used as a water height detector. The gage cable was 250 ft of 2-conductor 16-gage plastic-covered extension cord wire with a 2-pin connector installed on the end opposite the gage. Extension cable was fabricated to locate the gages up to 700 ft from the instrumentation trailer.

14. The associated gage instrumentation consisted of: (a) a commercial 3-kHz power supply, (b) an a-c to d-c converter (demodulator), (c) a calibration circuit, and (d) a 24-point strip chart recorder. Figure 2 shows the basic circuit diagram. The gages were calibrated by varying R_1 and input voltage so that full-scale (10-in.) deflection on the recorder was obtained with the gage in air and half-scale (5-in.) deflection with the gage inserted in water. With this calibration, grout detection was indicated by approximately a 1-in. deflection. These deflections were attainable because of the characteristics of the exciter-demodulator. If the voltage is measured across R_1 with an a-c voltmeter, an air reading would be 0 volts and a grout reading would be close to the applied voltage magnitude.

Pressure Measuring System

15. The system for making pressure measurements in encased drill holes through the structure slab was assembled and calibrated in the laboratory. Commercial pressure transducers having a range of 0-50 psi were installed in waterproof housings. Four-conductor shielded cable was used to transmit the gage excitation voltage and gage output. The transducers were calibrated over the range of 0-30 psi with the field instrumentation cable installed.

16. The measuring system consisted of the following: (a) pressure transducer, (b) 5-volt DC regulated power supply, (c) multiple channel

balancing network, and (d) multi-point strip chart recorder. The basic system circuit diagram is shown in Figure 3. The transducer was adapted to a fixture for attaching to a balloon packer for sealing off the hole during the pressure measurement period. Plate 3 is a photograph of the pressure transducer, waterproof housing, and balloon packer.

Other Instrumentation

17. Water-height detectors were fabricated for the purpose of making quick and simple pressure measurements in the field. Since the drill holes were to be encased, a measurement of the height of the column of water indicated the pressure under the slab. A detector consisted of two electrodes separated by a dielectric connected to a d-c power supply and measuring instrument by a two-wire cable. Figure 4 shows a typical circuit. When water comes in contact with the electrodes, current flows in the circuit and a voltage is developed across R_1 and is indicated on the multi-point recorder. The smaller detector shown on Plate 2 was used as a water height detector.

18. Thermistors were encased in a weighted tube for lowering into the holes to monitor temperature at various locations. A digital readout device with built-in signal conditioning and calibration circuitry was used to monitor the thermistors.

PART III: FIELD OPERATION - GROUTING INSTRUMENTATION

Mobilization

19. In October 1973, members of the staff of the WES Concrete Laboratory were requested by NOD to fabricate the instrumentation discussed in Part II of this report. The grouting operation was to begin November 1973. Twenty grout detectors, 10 water level detectors, and 12 pressure transducers were fabricated. Many extension cables were prepared for long runs up to 600 ft from the instrumentation trailer.

20. Prior to the beginning of the pumping operation, the extension cables were laid out to various sections of the structure from the instrumentation located on the south end of the structure. Gages were connected and calibrated. The pressure calibrations were field checked using a 40-ft column of water contained in 1-1/2-in. PVC pipe supported from the structure.

Field Measurements

21. The pumping operation began on Thanksgiving Day, 23 November 1973. Eighteen grout detectors were installed in gate bays 8, 9, 10, and 11 at MSL elevations of -9.2 to -45.0 ft (81.2 to 119 ft below the bridge deck) through cased drill holes. Two water-height detectors were installed in gate bays 8 and 9. Six pressure transducers were mounted in balloon packers and installed in gate bays 8 and 10. After locating the pressure gages at the desired elevations, the packers were inflated to seal off the holes above the transducers. Plate 4 is a photograph of a pressure gage and packer assembly.

22. Prior to beginning the grouting operation, the grout detectors were located approximately 1 ft above the bottom of the cavity. When the grout level reached a detector, a corresponding large deflection occurred simultaneously on the strip chart recorder. At this time, the proper authority was notified of the grout elevation and the grout detector was

was raised 1 ft. It was found that the grout level could be located within 1/2 in. at a depth of 119 ft below the bridge deck. The grout detectors were moved to other holes as needed. A maximum of 24 detectors was used simultaneously at one period during the grouting operation requiring fabrication of additional detectors. Plate 5 shows the recorders and conditioning equipment for the detectors.

23. Additional instrumentation included thermistors for monitoring grout temperature and water-height detectors to supplement the pressure gages. The temperature measurements were included at the request of an OCE representative. These data were acquired from several locations under the slab for a period of several weeks. Since the holes were cased, a measurement of the height of the column of water was an indication of the pressure under the slab. The water-height detectors were used primarily as pressure alarm devices. The detectors were located approximately 2 ft above the water level requiring a 2-ft (0.866-psi) rise in the water column to activate the measuring system.

24. The grouting operation continued through February 1974, and extended into gate bays 6 and 7. Pressure and grout flow monitoring also continued through this period. After the major grouting operation had ceased with the major cavities filled, check borings were made to depths corresponding to the depth of the underlying foundation material. These borings revealed continuous grout material from the base of the slab to the base of the original cavity. Check borings continued in other bays and all small voids located were filled with grout. Grout detectors were used during this period where applicable.

25. Pressure gages installed in packers were used later in the year when additional check borings were made. During the summer of 1975, open hole piezometers were installed in several of the piers of the structure. The drilled holes extended to the base of the piers. Immediately after each hole was completed, the pressure was monitored for a period of time sufficient for pressure stabilization.

PART IV: RESULTS

26. The grout detectors were used during all grouting exercises at many locations around the injection hole to determine both the height of grout and the flow. The data from these gages were used to determine when the grouting should cease in a particular area and how well the grout was flowing into other areas. As indicated previously, grout height could be determined within 1/2 in. at distances up to 119 ft.

27. Not only would the grout detector differentiate between water and grout, but it would also detect bentonite and other materials mixed in water. When installed in the hole below water level, it would detect the fluff or water contaminated with cement. While pure grout gave deflections 1 in. from zero on the strip chart, a contaminated water would cause a deflection of 1-1/2 to 3 in. depending on degree of contamination. Muck gave a deflection of approximately 3-4 in. If the gage was located in a strong current, the deflection was approximately 6-7 in. because of the air bubbles created due to agitation.

28. The pressure transducers were used to insure against building up an excessive uplift pressure during the grouting. The transducers worked well and gave data pertinent to the operation. However, much care had to be taken to insure against cable and transducer damage. Moisture entering the cable through cuts in insulation caused erratic operation. Several transducers were damaged and were not repairable because grout penetrated their housings.

PART V: CONCLUSIONS

29. The grout detectors and pressure gages were very significant in the success of the grouting operation. As previously stated, as many as 24 grout detectors were used at one time. The success of these gages has led to their use at other installations.

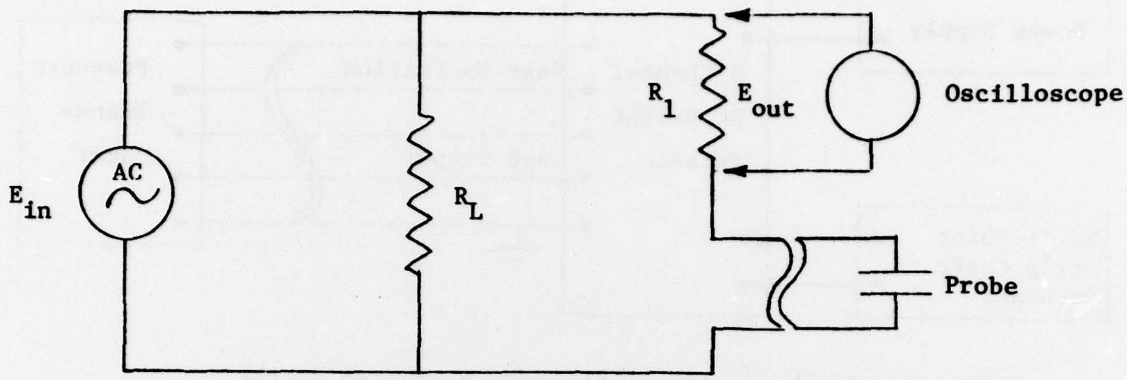

Figure 1. Basic experimental grout detector circuit

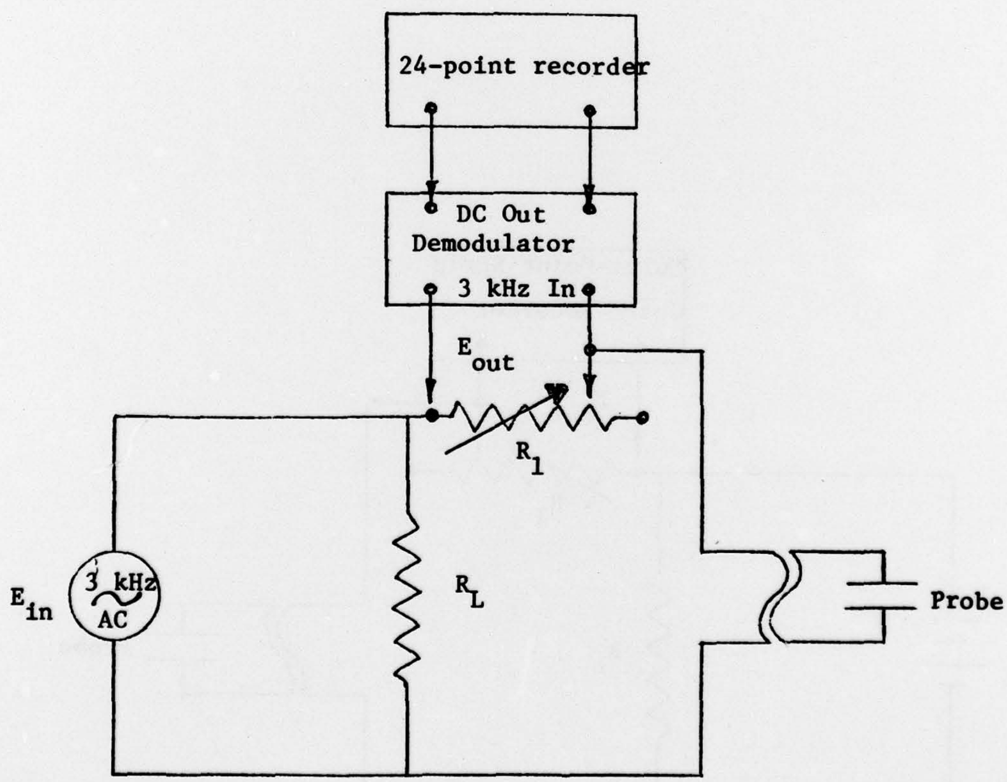

Figure 2. Basic field grout detector circuit

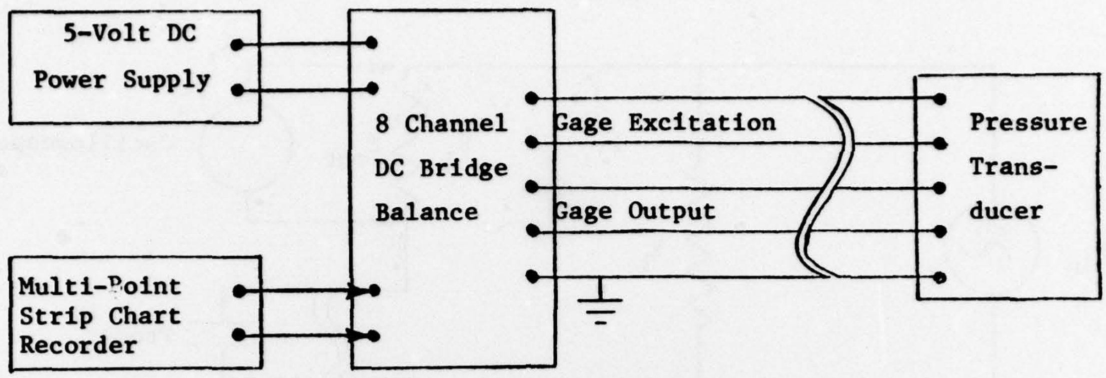

Figure 3. Block diagram of pressure measuring system

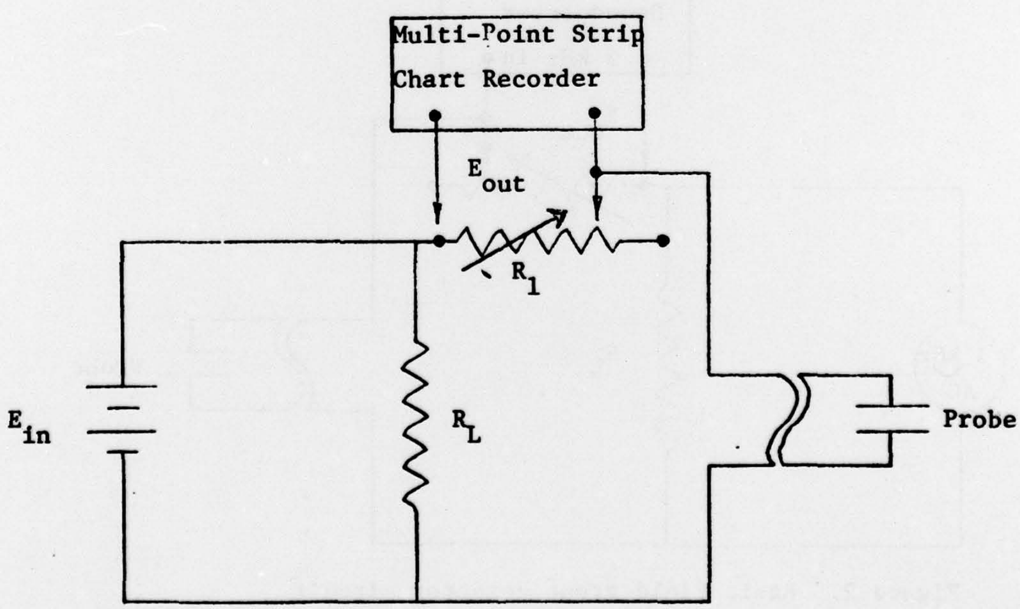

Figure 4. Water-height indicator circuit diagram

Plate 1. Old River Low Sill Control Structure.
General view from stilling basin side

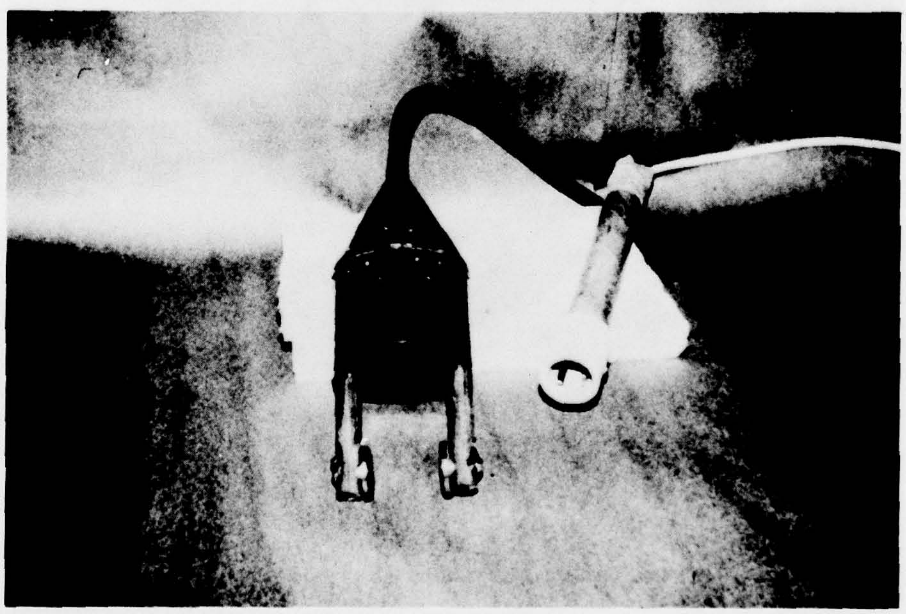

Plate 2. Grout and water height detectors

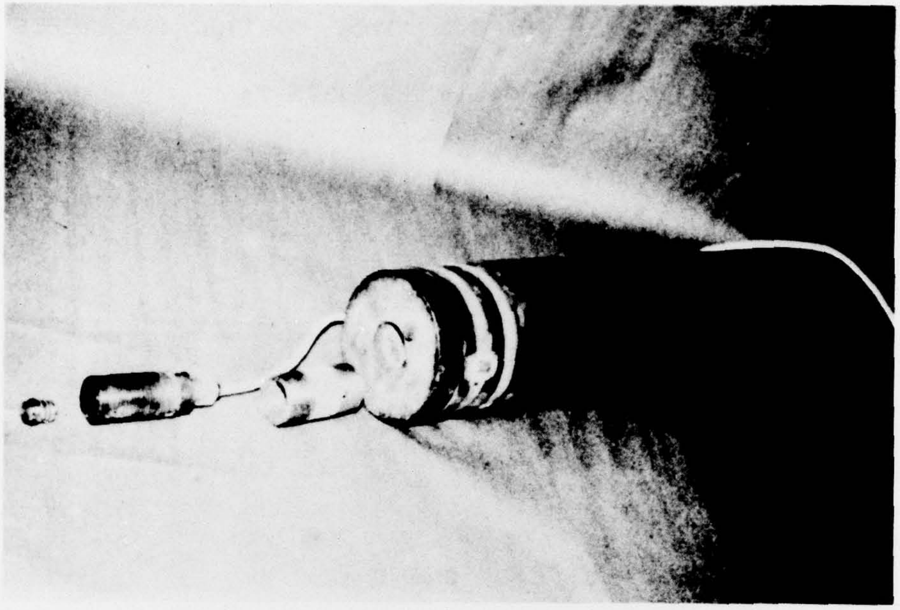

Plate 3. Disassembled pressure gage-packer system

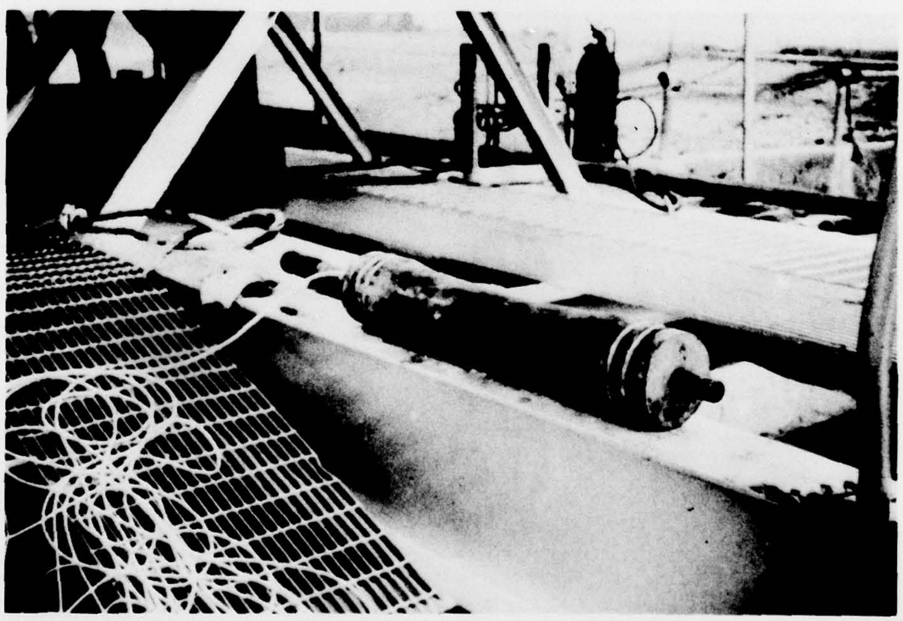

Plate 4. Pressure gage-packer assembly

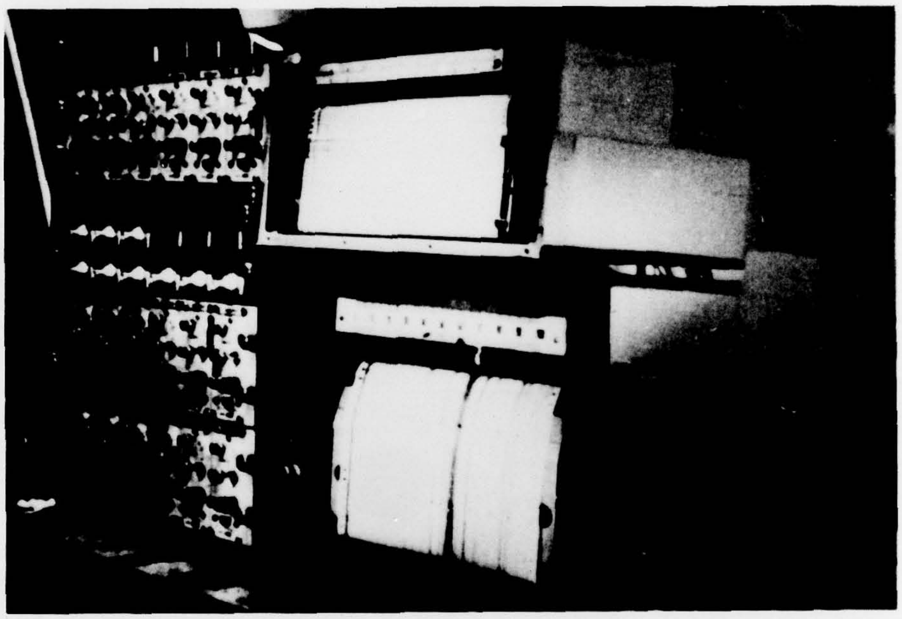

Plate 5. Recorders and conditioning equipment for grout detectors

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